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**Avco
EVERETT**

**RESEARCH
LABORATORY**

a division of
AVCO CORPORATION

DESIGN, DEVELOPMENT, AND TEST
OF A PROTOTYPE SELF-EXCITED MHD GENERATOR

SEMI-ANNUAL TECHNICAL SUMMARY REPORT

Contract No. AF 33(657)-8380

September 1963

supported by

ADVANCED RESEARCH PROJECTS AGENCY

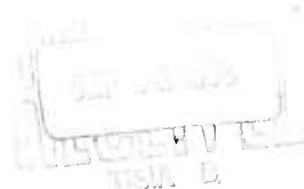
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AIR FORCE SYSTEMS COMMAND

AERONAUTICAL SYSTEMS DIVISION

Wright-Patterson Air Force Base, Ohio

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ARPA Order No. 291-62
Project Code No. 9800

I. INTRODUCTION

The period covered by this report has been devoted to fabrication, assembly and test of the various generator components and their auxiliary systems.

The previous Semi-Annual Technical Summary Report described the burner design. Since that time we have made minor alterations of the burner design due to problems which arose during the fabrication of the various burner components, mainly the injector assembly. These problems and how they have been attacked are described in Section II.

During careful analysis of the cooling water system in the pilot burner, it came to our attention that the safety factor on burnout was too small. The problem was solved by lowering the enthalpy of the combustion gases by dilution with nitrogen. This resulted in a modification of the pilot burner control system. In addition, we have also made some modification of the main fuel system and oxygen system. This work is described in Section III.

The design of the generator channel was completed in the beginning of the period covered by this report, but, to incorporate the newest technology achieved from various tests performed, we have made minor modifications in the detailed channel design. These modifications are described in Section IV.

An instrumentation system has been designed to measure generator performance and to monitor the functioning of the control system. The instrumentation design is reported in Section V.

Construction of generator components and auxiliary systems has reached the point where some testing can be started. A description of the testing that has been done will be found in Section VI.

Section VII is a description of the present status of the Mark V MHD Generator construction.

II. BURNER

Assembly and test of the burner have been delayed because of problems in fabrication. The sources of the defects are both in design and workmanship. The design of this burner was subcontracted. The injector design which evolved is, in retrospect, much more suitable for flight weight hardware and quantity production than for use in the MHD generator. Success with the all-welded structure is greatly dependent on the skill of the welder. The selected hot face material, Inconel X-750, requires meticulous care during welding and heat treating to secure a sound structure and suitable mechanical properties.

The sequence of events with the injector plate was as follows: The first attempt at fabrication resulted in failure when the piece was only partially finished. At this time a fairly simple and effective repair cycle was evolved which should have produced a satisfactory piece. The local technical representative of the Huntington Alloy Division of International Nickel Company, makers of Inconel Alloys, was consulted at this time, and his recommendations were incorporated into the repair cycle. At the conclusion of welding and heat treating, the injector was found to have many cracked welds with cracks in some cases running into the base metal. Figure II-1 shows an oxygen nozzle welded into place with typical cracked welds. The failure was attributed to lack of proper cleanliness in making the welds and failure of the heat treater to follow instructions regarding heating rate. Figure III-2 of the March 1963 Semi-Annual Report shows the complete injector assembly.

At the conclusion of the repair cycle the injector assembly was carefully inspected by both X-ray and dye penetrant methods. As a result of this inspection a second repair cycle appeared feasible which would cut out all weld metal and replace those parts which showed cracks. About eight out of sixty oxygen nozzles were replaced and a new injector face plate was made. All work was performed by new vendors under constant supervision by Avco personnel. At the conclusion of welding and heat treating, the welds were all sound, but some of the oxygen nozzles had developed cracks. The cracks in the nozzles had possibly developed from small undetected cracks which were present after the first rework, or from some metallurgical deterioration of the material. In its present state this injector plate is considered to be useable at low mass flows despite the fact that some slight water leakage may be expected into the oxygen nozzles. So long as the oxygen injection pressure is lower than the water jacket pressure, which is the case up to 40-45% of normal mass flow, there should be no hazard in using this injector assembly. Accordingly, the simple finish machining operations are being done so that we may start burner testing.

Since the first injector assembly is not suitable for operation at full mass flow, the construction of a second injector assembly has been started. A material change to Type 347 stainless steel has been made to reduce the

likelihood of defective welds and to eliminate heat treatment. As in regard to material properties, there is a considerable loss of yield strength, but a gain in ductility as compared to Inconel X-750. Since this piece operates in a low cycle fatigue regime, the net loss in life appears to be small. In addition, the burner design basis for stress and heat transfer was 120% of normal flow. It now appears that we may achieve full generator output at somewhat less than normal flow, and therefore at considerably lower values of stress and heat transfer in the burner.

In the design of the cooling passages in the injector plate, it was anticipated that some flow guides might be required to assure good cooling at all locations. Specifically, the water flow is perpendicular to the cylindrical exterior of the oxygen nozzles and a stagnant wake was expected behind each oxygen nozzle. To locate the stagnant areas, a transparent plastic window was attached to the injector plate in place of the Inconel face. Water flow was then established through the cooling passage and flow visualization obtained by injecting dye. Optimum locations for baffles and flow guide wires were determined in this manner. A photograph of this test set-up is shown in Fig. II-2.

Careful analysis of the cooling system in the pilot burner as designed indicates that safety factor on burnout is rather small. Dependable operation of the pilot burner is considered an essential safety feature for our application. Various ways of increasing the burnout safety factor were considered, and the most satisfactory appeared to be by nitrogen dilution. Diluting the oxygen flow with nitrogen will reduce the combustion gas enthalpy and the gas-to-wall heat transfer rates. A nitrogen-oxygen ratio of one was selected, which will increase the safety factor on burnout by approximately a factor of two.

A modification of the pilot burner control system permits controlled nitrogen dilution. This modification will be described under Auxiliary Systems.

The pilot burner is started by means of a small igniter burner which need operate for only a few seconds. Figure II-3 shows a cross-section of this burner. Oxygen and ethane are injected as shown and ignited by a sparkplug. The design injection pressures are 500 psig and the desired chamber pressure is 250 psig. The burner is water cooled, but due to the construction of the pilot burner, it is impossible to properly cool all of the throat section. Because of the partial cooling of the throat, the running time must be limited to a few seconds at the beginning of a generator run.

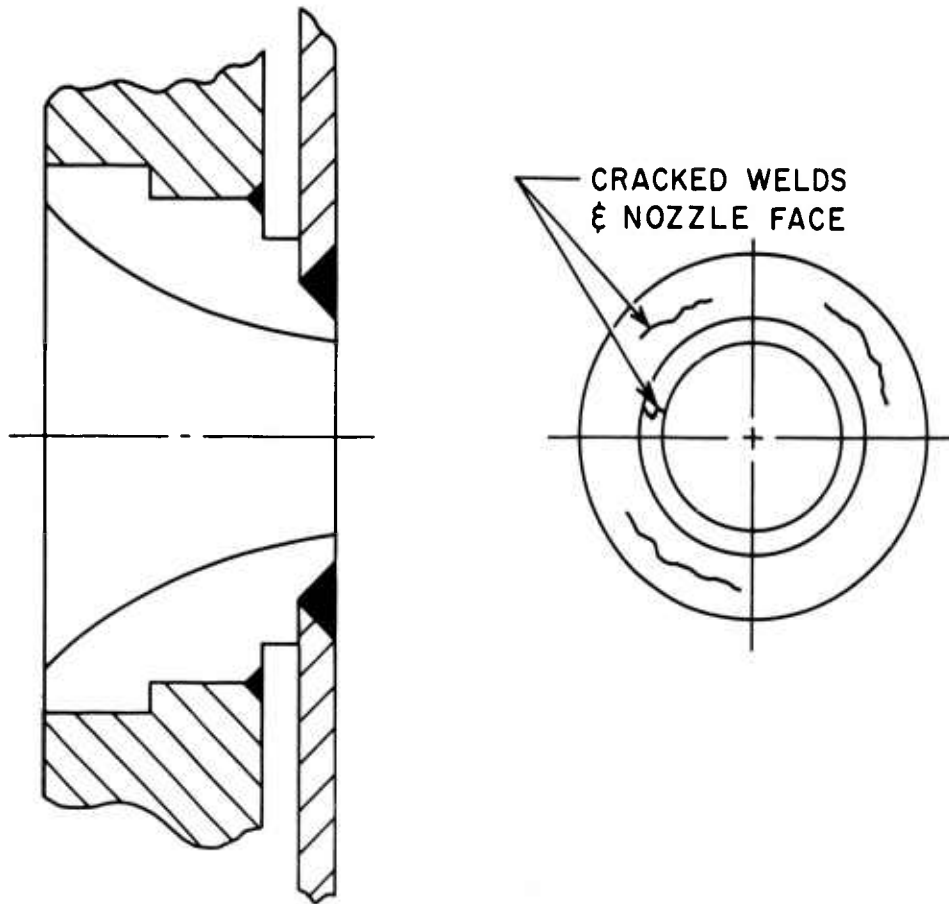


Figure II-1 Oxygen Nozzle Showing Defective Welds

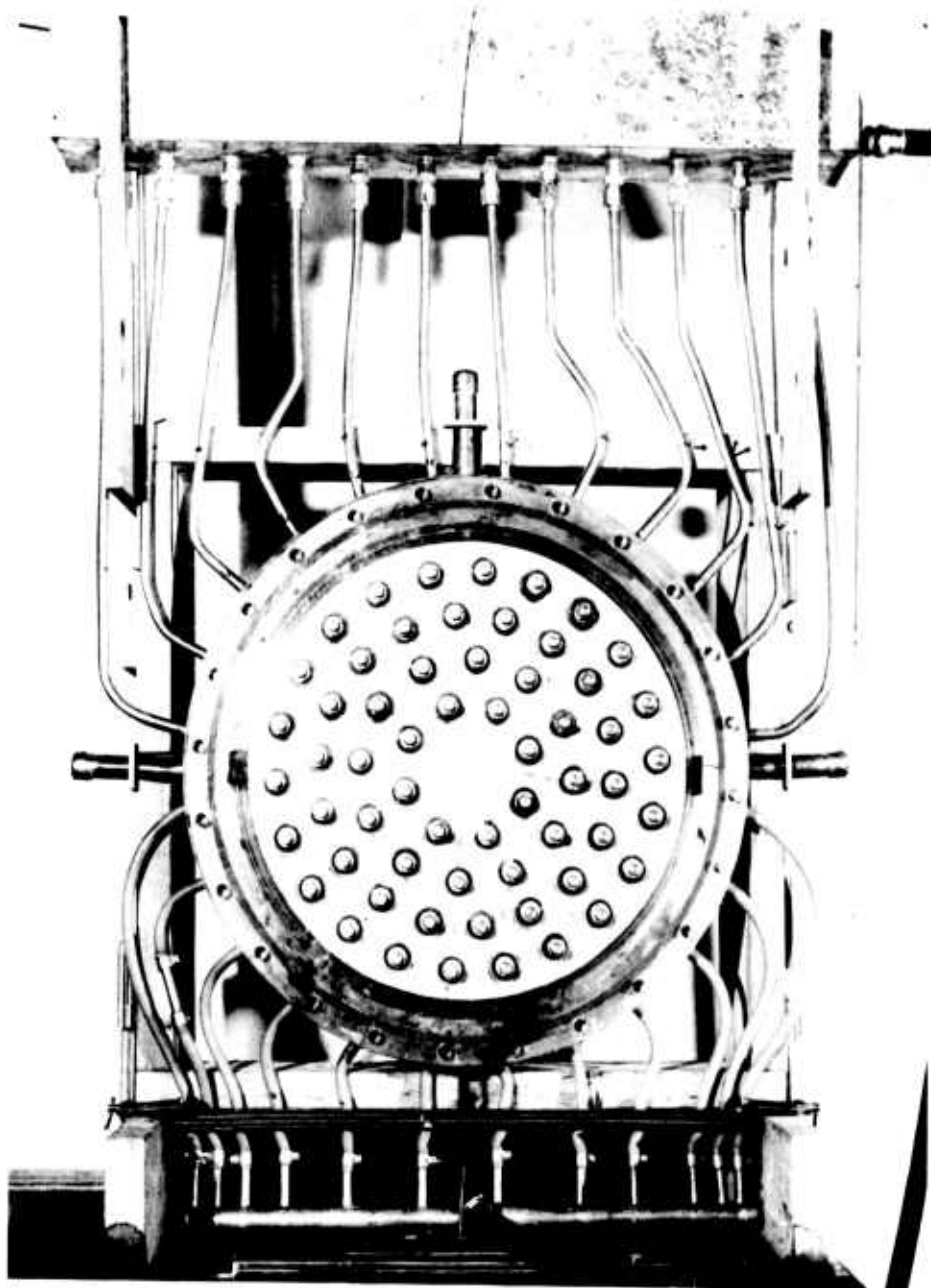


Figure II-2 Burner Injector Plate Setup for Cooling Water Flow Tests

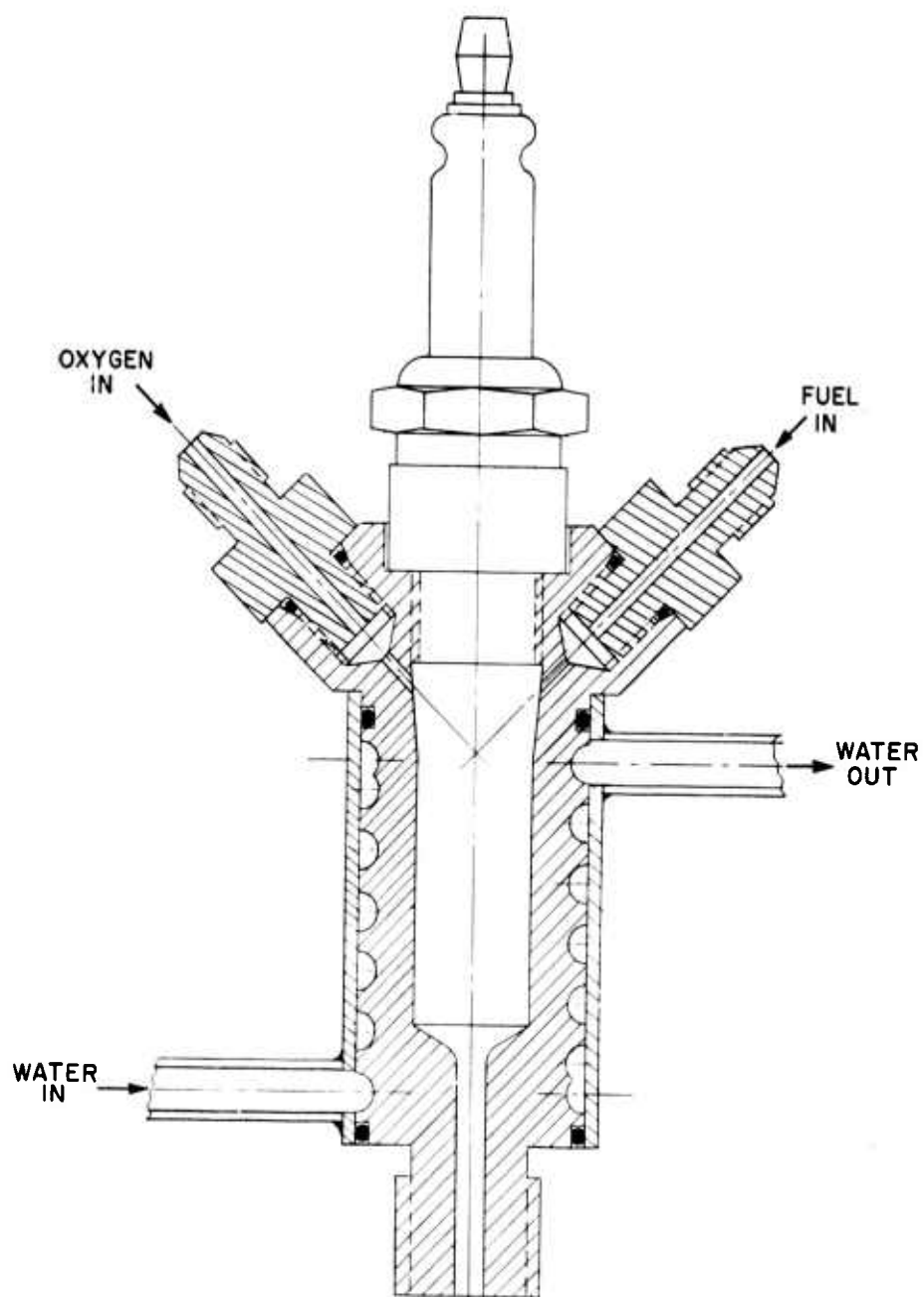


Figure II-3 Cross Section of Igniter Burner

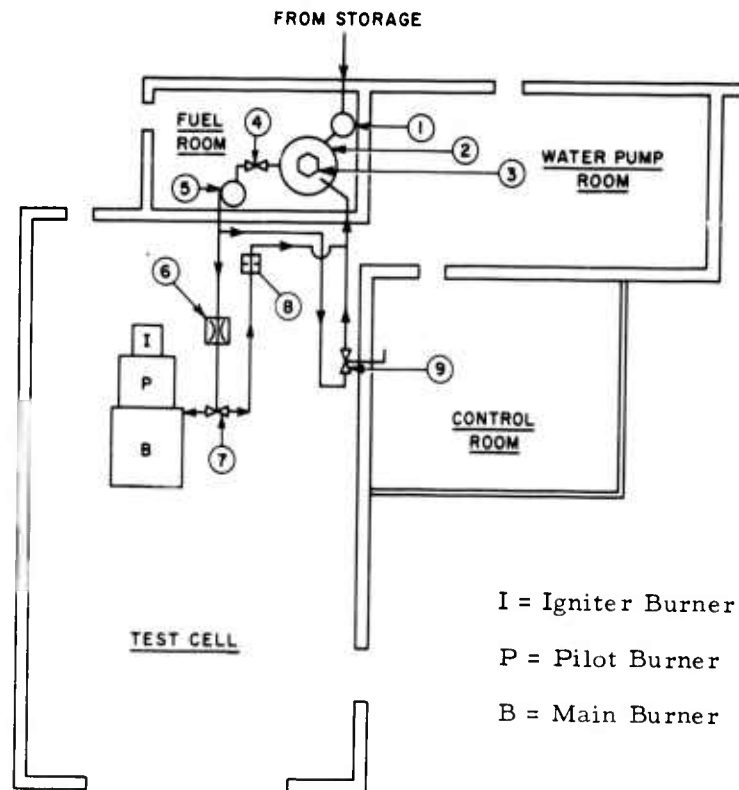
III. AUXILIARY SYSTEMS

Fuel System: The final design of the fuel system has been slightly modified from the description presented in the last semi-annual report. The modified system is shown in Fig. III-1. A three-way remote control valve is now used to direct fuel flow either to the calibrating loop or the burner. The calibrating loop contains an orifice with hydraulic impedance equivalent to the burner fuel injectors. The sequence for starting the burner is to start the main fuel pump with the valve open to the calibrating loop, then adjust the bypass valve to produce the desired flow as indicated by the venturi, and then divert the fuel flow by means of the three-way valve from the calibrating loop to the burner. If the calibrating orifice is truly equivalent to the burner injectors, the fuel flow to the burner should be correct. The system flows will be checked with water during burner calibration and test.

In order to assure proper operation of the fuel system over the full range of 25% to 100% flow, three sets of fuel injectors, fuel venturies and calibrating orifices are required. In sizing the fuel injectors, a minimum safe injection pressure drop was selected, and the injectors were sized for the required flow at this pressure. The maximum flow for any injector set is limited by the pump pressure at that flow. Figure III-2 is a fuel system performance curve which illustrates the flow characteristics of each injector set. The following example will illustrate the working of this chart. Suppose a flow of 250-gpm is required. The 250-gpm line intersects the medium size injector characteristic curve. Using the medium size injectors, the 250-gpm line intersects the dotted curve at 325 psig, which is the fuel injection pressure drop. The 250-gpm line intersects the solid curve at 410 psig, which will be the pump discharge pressure. At 410 psig the total output of the pump is 525-gpm, of which 250-gpm will go to the burner and 275-gpm will be bypassed back to the fuel tank. If the oxygen-fuel mixture is stoichiometric, the corresponding burner chamber pressure will be 60 psig.

Oxygen System: The oxygen venturi is designed to operate with critical flow (sonic velocity in the throat). Critical flow operation simplifies the instrumentation because it is only necessary to measure initial pressure and temperature. However, the oxygen storage system is small in relation to the quantity of gas removed during a full duration run, and a considerable drop in temperature will occur. In addition, a further temperature drop will occur at the throttle valve. In the worst case the oxygen temperature at the venturi throat can be as low as 140°K. At this temperature and at the pressures corresponding to 100% mass flow, there is considerable departure from ideal gas laws. The oxygen venturi flow chart shown in Fig. III-3 was constructed from information obtained from a Bureau of Standards publication.

Pilot Burner Control: A revised pilot burner control was designed to provide the nitrogen dilution required as previously described. The modified control is shown in Fig. III-4. The two additional elements are the nitrogen solenoid valve, Item 2, and the mixing venturi, Item 4. The nitrogen valve, 2, will open simultaneously with the oxygen valve, 1. The mixing venturi will proportion the nitrogen and oxygen flows. The mixing venturi contains two concentric entrance cones, one for each gas, and a single diffuser. The inner, or oxygen, cone is adjustable axially to permit varying the area of outer, or nitrogen, cone. By suitable adjustment the desired degree of nitrogen dilution may be obtained.



- 1 Transfer Pump
- 2 Fuel Tank
- 3 Mixer
- 4 Main Fuel Shut-off Valve (Manual control)
- 5 Fuel Pump
- 6 Fuel Venturi
- 7 Three-Way Fuel Valve (Remote control)
- 8 Restriction Orifice
- 9 Fuel By-Pass Valve (Manual control)

Figure III-1 Modified Fuel System Schematic

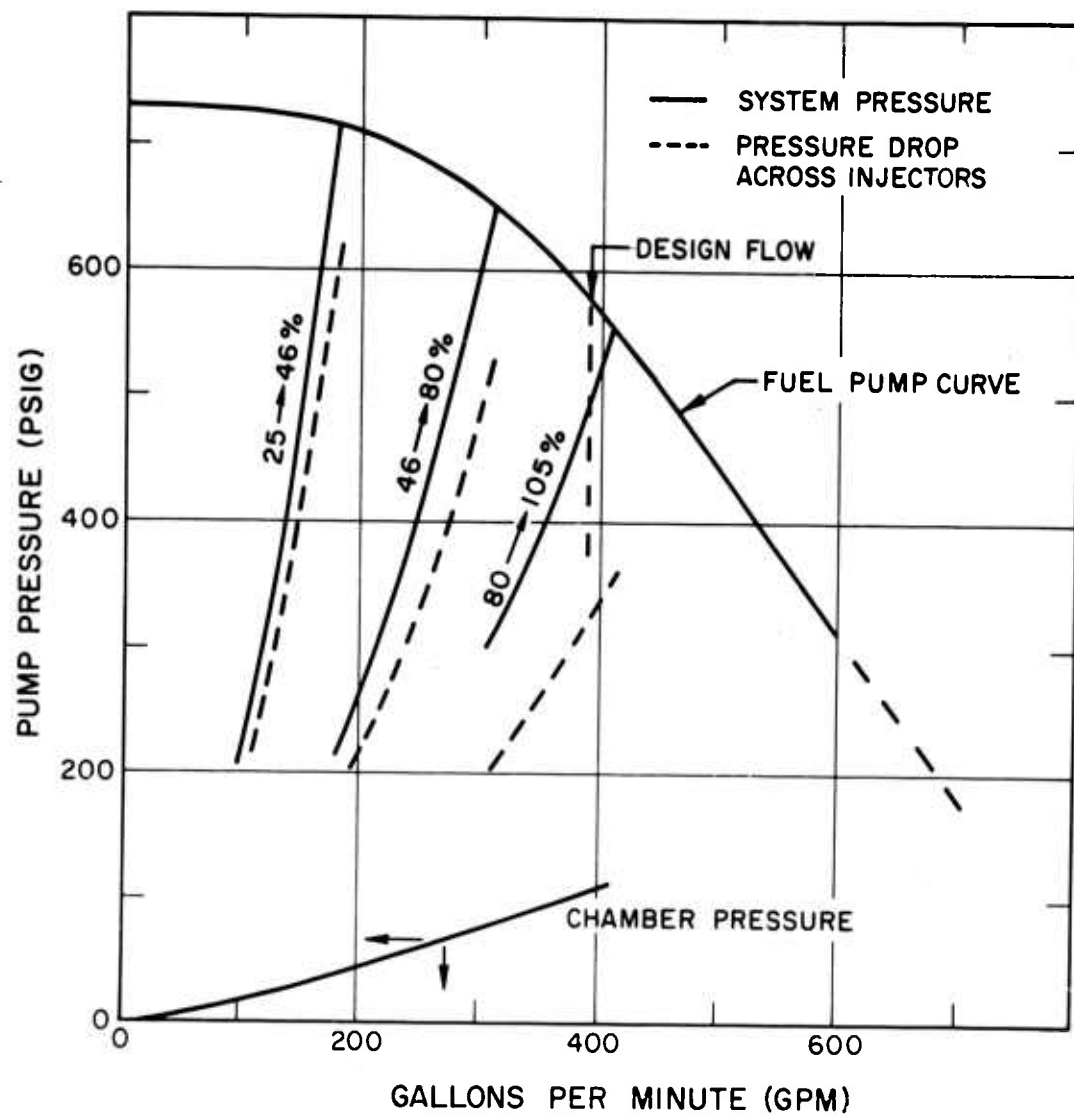


Figure III-2 Fuel System Characteristics for the Mark V Generator

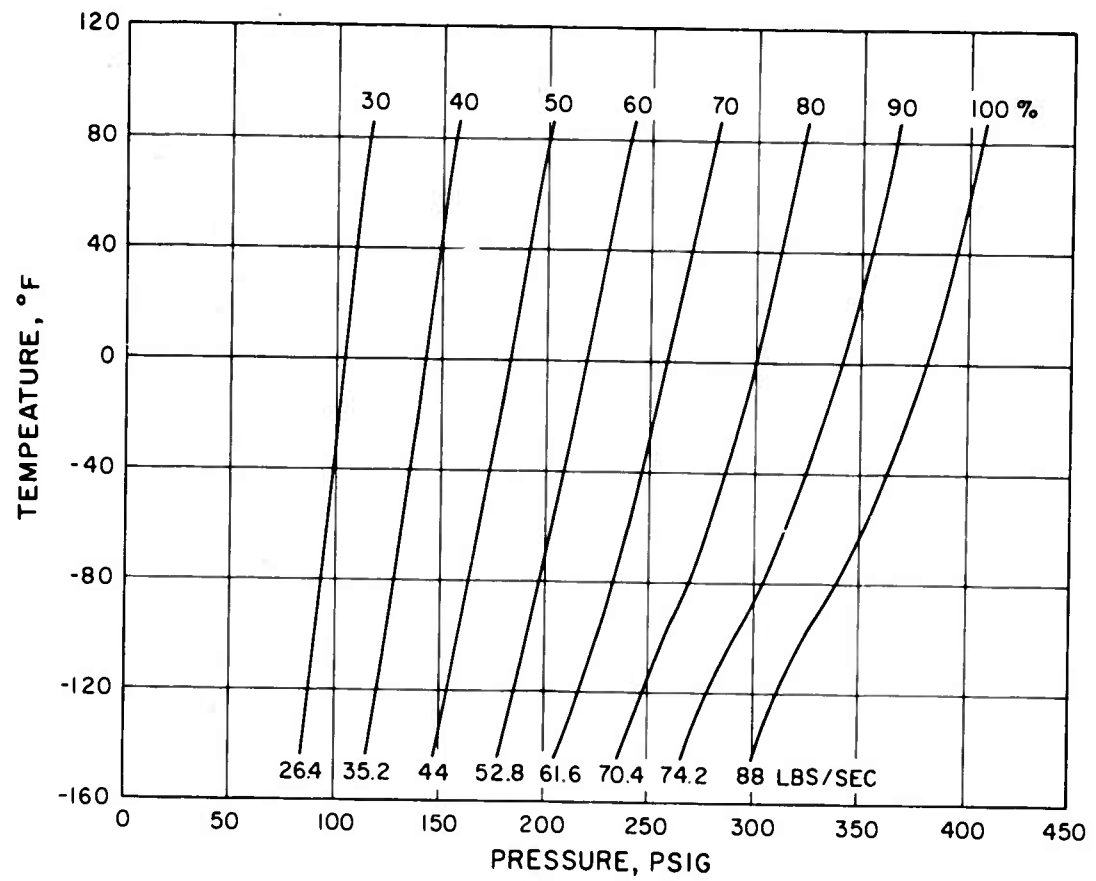
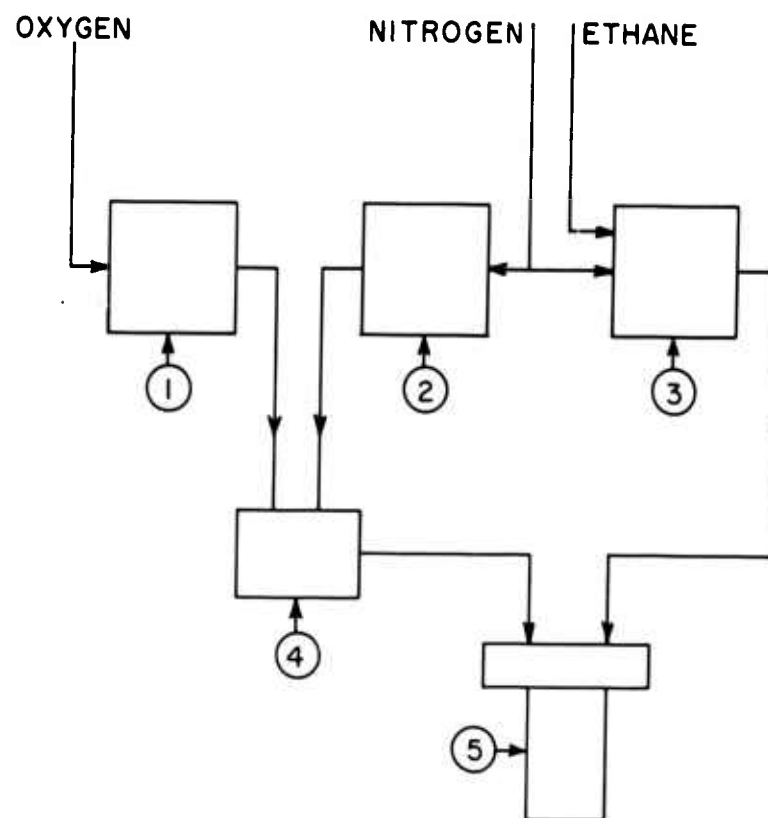


Figure III-3 Oxygen Venturi Flow Versus P_1 and T_1



1. OXYGEN SOLENOID VALVE
2. NITROGEN SOLENOID VALVE
3. NITROGEN-ETHANE THREE -WAY SOLENOID VALVE
4. MIXING VENTURI
5. PILOT BURNER

Figure III-4 Revised Pilot Burner Control System

IV. GENERATOR CHANNEL

The channel design has been slightly modified to include the newest technology of channel construction. The design has been completed and assembly is in progress.

The total allotted channel water flow rate, reported as 2500-gpm in the previous summary report, has been increased to 3500-gpm in order to lower the wall operating temperatures and water bulk temperature rise. The purpose of this change is to increase the endurance limit of channel walls. Each insulating wall will now receive 1120-gpm, resulting in a bulk rise of 68°F at 120% rated gas flow rate; each electrode wall will now receive 630-gpm with a water temperature rise of 99°F. Curves showing heat transfer rates and revised design surface temperatures resulting from the increased water flow are shown in Fig. IV-1. The new total water flow rate will be 3500-gpm with an additional 300-gpm to cool the channel inlet flange.

Electrical taps have been designed to transmit power from the electrodes to the load leads. The path to conduct the power from the channel will be made up of copper electrodes and their individual stainless steel reinforcing bars. Four lugs will then conduct the power through the plastic insulating wall to copper bus bars outside the channel. The bus bars extend above and/or below the channel depending on the electrode function. These bars are then connected to other bus bars if their power is to be used in the load resistors.

A discussion of the channel instrumentation design may be found in Section V of this report.

To operate and test the burner before the channel assembly is complete, a dummy channel has been designed and constructed. The design of the dummy channel consists of an inlet flange used to connect the channel to the burner. The channel is then made of two concentric pipes which form an annulus for cooling water flow. The pipes are connected together structurally at strategic points along the channel length to prevent buckling of the internal pipe. A cooling water flow of 2500-gpm passes through the annulus, and is discharged through orifices at the end of the pipe directly into the exhaust duct.

Another 1500-gpm of water is injected through orifices at the inlet flange to partially quench the hot gas on the inside surface of the pipe. This injection is required to reduce thermal stresses to a tolerable level. The dummy channel is mounted on rollers so it can be moved on the same rails, inside the magnet, which support the channel. A photograph of the completed dummy channel may be seen in Fig. IV-2.

An exhaust duct to conduct the gases from the channel to the atmosphere has been designed and constructed. This duct is eight feet in diameter and thirty-five feet long. It is designed with three sets of casters so that it may be rolled away from the channel. The purpose of this is to be able to remove the channel from inside of the magnet. Cooling water from the load resistors is injected into the gas stream through a series of orifices drilled in a pipe located in the front end of the exhaust duct. A photograph of this duct in its test position may be seen in Fig. IV-3.

Since the channel is being assembled at the Avco/Everett Research Laboratory, and will be transported to the Haverhill Test Facility, it was necessary to insure a proper fit of the channel inside the magnet and proper alignment of the channel with the various generator components. To accomplish this, a full-scale wooden mock-up of the channel was constructed and mounted on the real channel chassis and roll-out stand.

The centerline for the entire generator was then established, utilizing the completely fabricated channel roll-out stand, chassis, full-scale wooden mock-up of the channel (see Fig. IV-4), magnet, burner and burner cart. Using the established centerline, it was then possible to line up and install the rail system for the burner and channel in their final location.

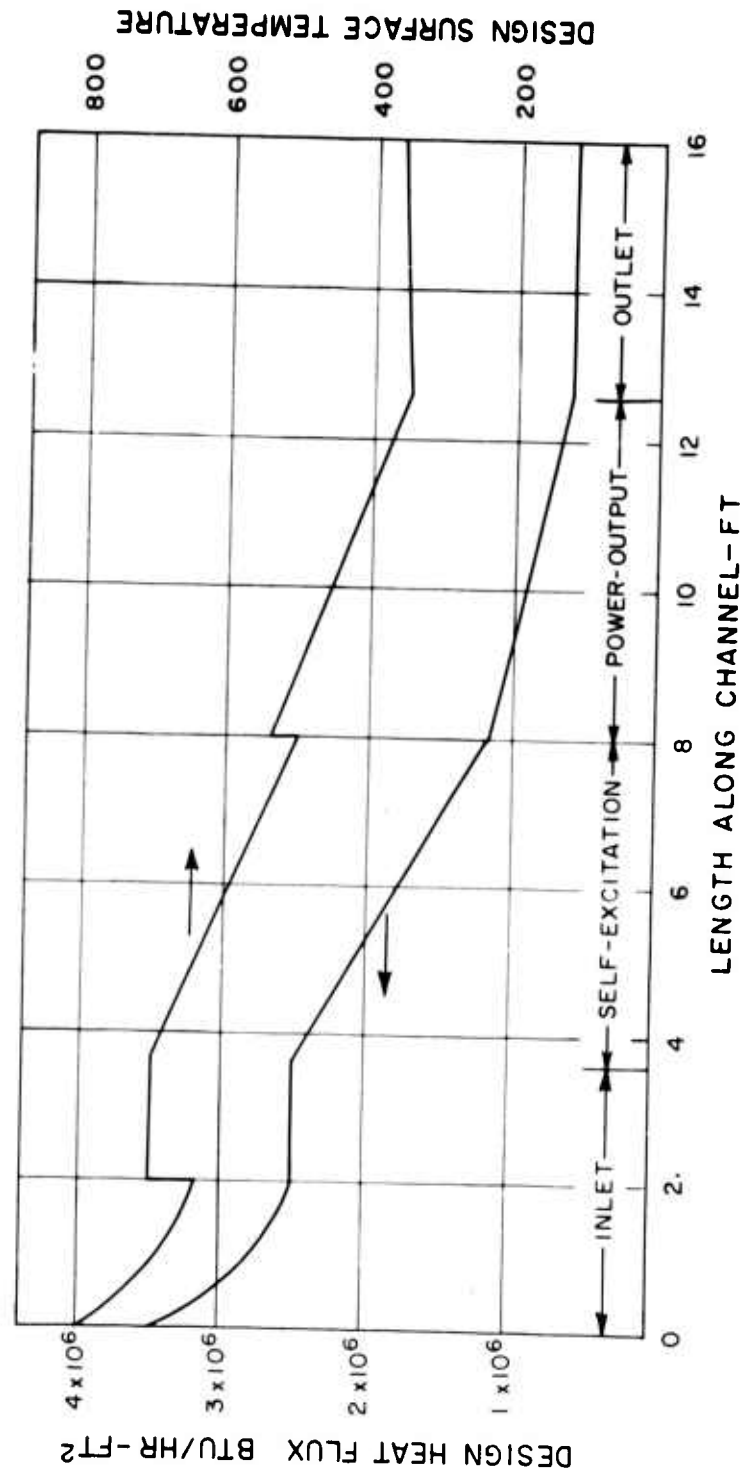


Figure IV-1 Heat Transfer and Surface Temperature for Insulating Walls at 120% Rated Gas Flow Rate

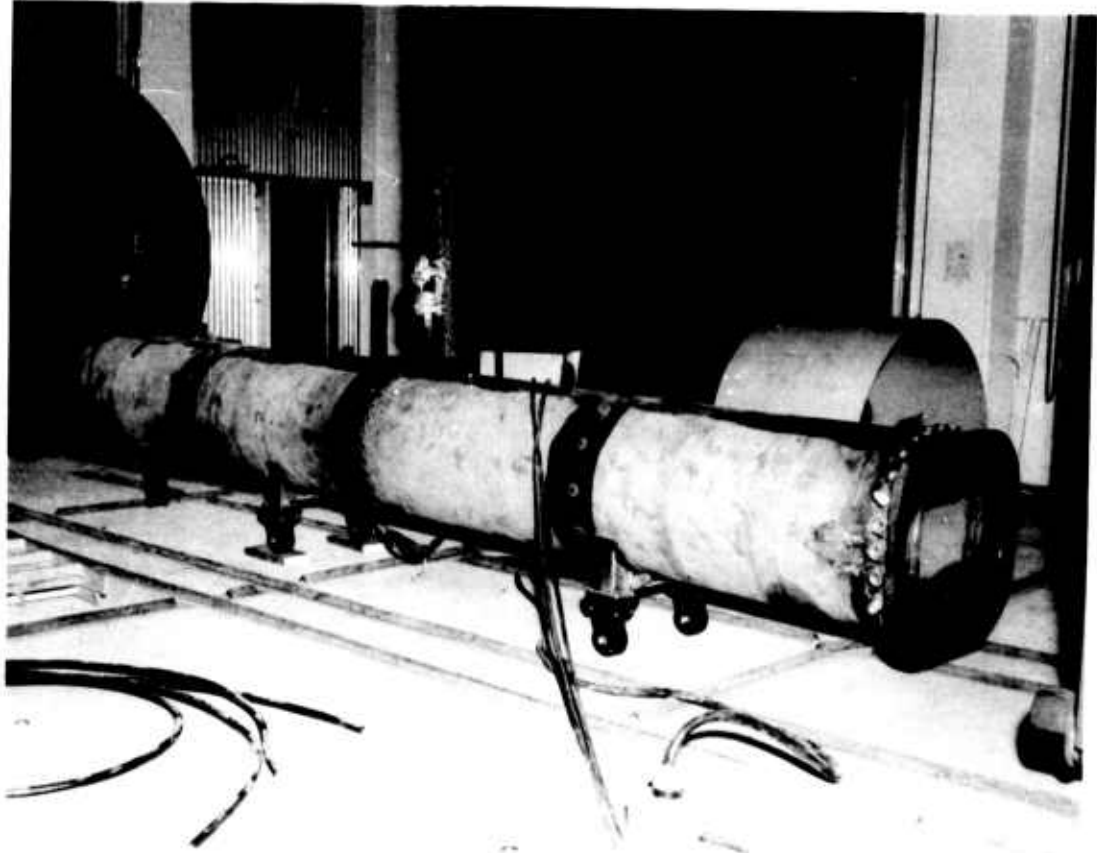


Figure IV-2 Dummy Channel

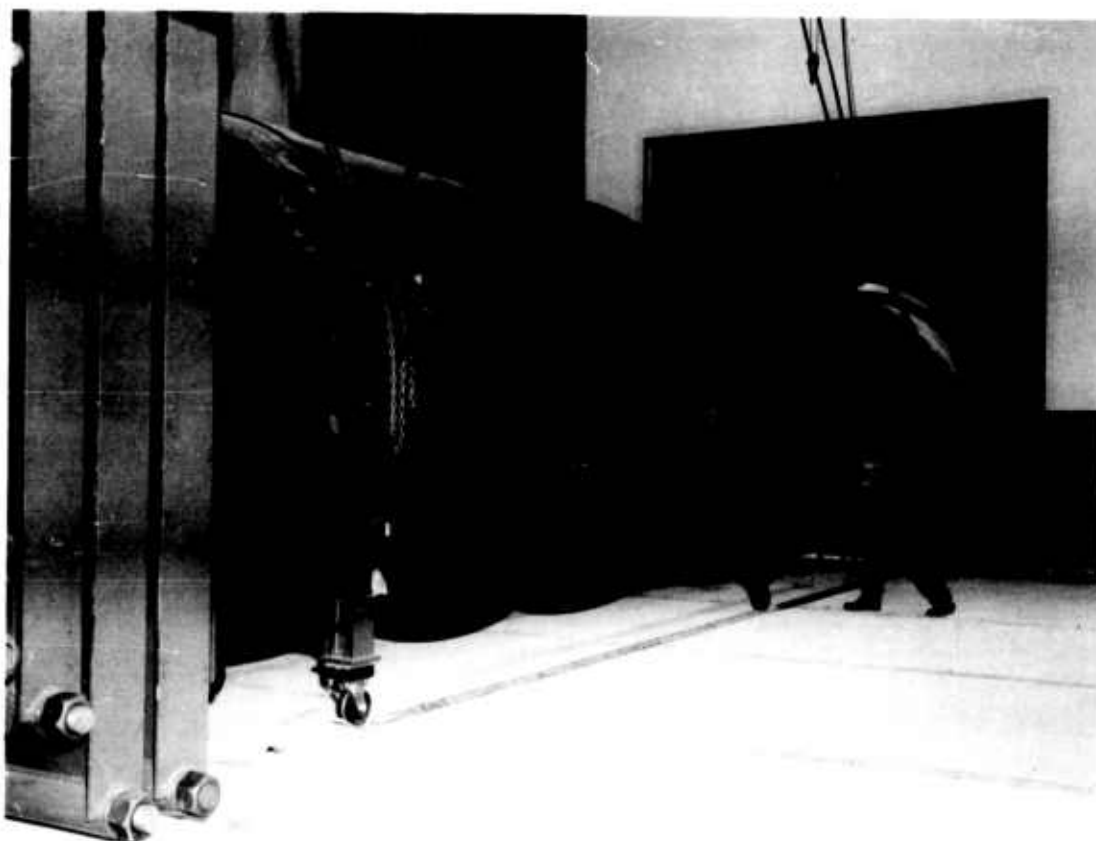


Figure IV-3 Exhaust Duct

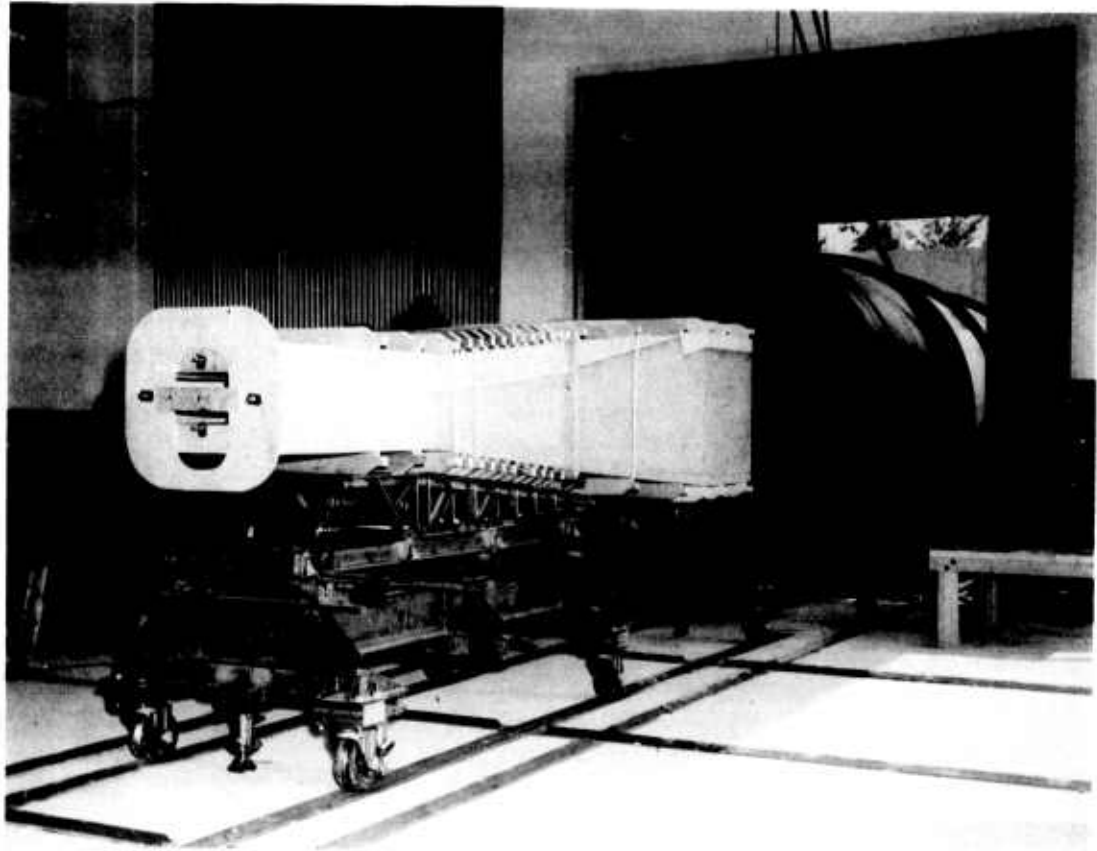


Figure IV-4 Wooden Mockup of Actual Channel on Roll-out Stand

V. INSTRUMENTATION

Instrumentation for the Mark V MHD Generator may be broken down into four sections: Channel monitoring, power monitoring, magnet control and burner operating control instrumentation.

1. Channel Monitoring Instrumentation: Figure V-1 is a sketch showing the location of the various channel measurements to be taken.

Pressure taps have been placed to measure both axial and transverse gas pressure distribution across one insulating wall. Eighteen centerline taps have been installed along with four transverse taps located in three positions in the power section of the channel. The four transverse taps, together with a centerline tap, provide a five-point distribution as indicated in Fig. V-1.

The bulk water temperature will be measured for a single water passage in one insulating and one electrode wall. Twelve thermocouples will be used in each wall, having a distribution as indicated in Fig. V-1.

The temperature measurements of channel cooling water will be taken only during non-power runs and recorded on a 24-channel multipoint recorder.

Six thermocouples are located in one quadrant of the channel exit to monitor the total water temperature before the water is discharged into the exhaust gases.

A transverse voltage distribution will be taken at three locations in the channel as shown in Fig. V-1. Nine points will be taken for each of the three locations.

Six Hall voltages will be measured between electrodes as indicated in Fig. V-1. Another Hall voltage will be taken from the exhaust duct and two total Hall voltage readings taken, one at the end of the power section and one at the exit of the channel.

Additional instrumentation will be used to verify calculated stresses and strains when the channel is subjected to loading. Strain gauges will be placed on the plastic walls and steel reinforcing bars while linear variable differential transformers will be used to measure any outward wall deflections. These readings will be taken during the static pressure leak check of the channel, using gaseous helium and during test runs utilizing combustion gas flow with no magnetic field.

2. Power Monitoring Instrumentation: To obtain the net power output of the generator, the current flow through 20 sets of load resistors will be measured. This is approximately every third electrode in the channel. The current flow through the loads will be obtained using a calibrated section of the stainless steel tube in each load as a shunt. The calibrating device is specially designed for the application and is adjustable for a limited range on the tube.

Six electrode pair voltages will be measured. These voltage values will not be taken on the same electrodes for which the current is measured. This data will be obtained by measuring the total voltage drop across the load resistor set.

3. Magnet Control Instrumentation: The total magnet current and voltage will be monitored and recorded as well as the total battery supply output. The magnet current is measured on a shunt connected between the channel self-excitation electrodes and the magnet. The magnet voltage is measured across the full magnet while the battery current is taken from a shunt on the battery switchboard.

The total magnet and battery currents will be recorded on a two-channel strip chart recorder and will be duplicated on meters for the instrumentation panel.

As a further check on the magnet pre-excitation rise time, there will be a time indicator displayed on the instrumentation panel which will start when the main exciter circuit switch is closed.

4. Burner Operating Control: To properly evaluate burner operation requires the recording of pressures and temperatures for the burner and auxiliary systems.

Pilot burner operation will be evaluated by recording the fuel manifold, oxygen manifold and chamber pressures.

Main burner operation requires a knowledge of the pressures in the fuel manifold, oxygen manifold, and combustion chamber. The bulk temperature rise and cooling water discharge pressure for the burner are monitored at six locations.

The cooling water pump discharge pressure and temperature will be recorded as will the temperature and pressure of the main burner oxygen as it flows through the flow control venturi.

The total bulk temperature rise and discharge pressure for each of the four load resistor manifolds will also be indicated.

In all, approximately 100 separate measurements will be made to evaluate the overall generator performance. To best display, record, and reduce data of such a large volume, it was decided to photograph an instrument panel on which the values could be displayed with fairly inexpensive

meters and gauges. To photograph these instruments two surplus K-25 aerial cameras will be used.

A power supply was designed to operate the cameras. The power supply makes it possible to operate either or both cameras continuously or the cameras can be timed to pulse separately or individually in combination with continuous operation.

At the present time it is planned to operate one camera continuously at a speed of one frame per second to record very closely the magnet pre-excitation, burner start-up, and magnet self-excitation. The second camera will be pulsed at approximately one frame every four seconds.

The film produces a picture which is 4" x 5" and sixty frames long. Using adapter lenses for fixed distances it is possible to record the entire panel with each camera so that all data is on a single roll of film.

A photograph of the partially assembled instrument panel, cameras and strip chart recorders may be seen in Fig. VII-11.

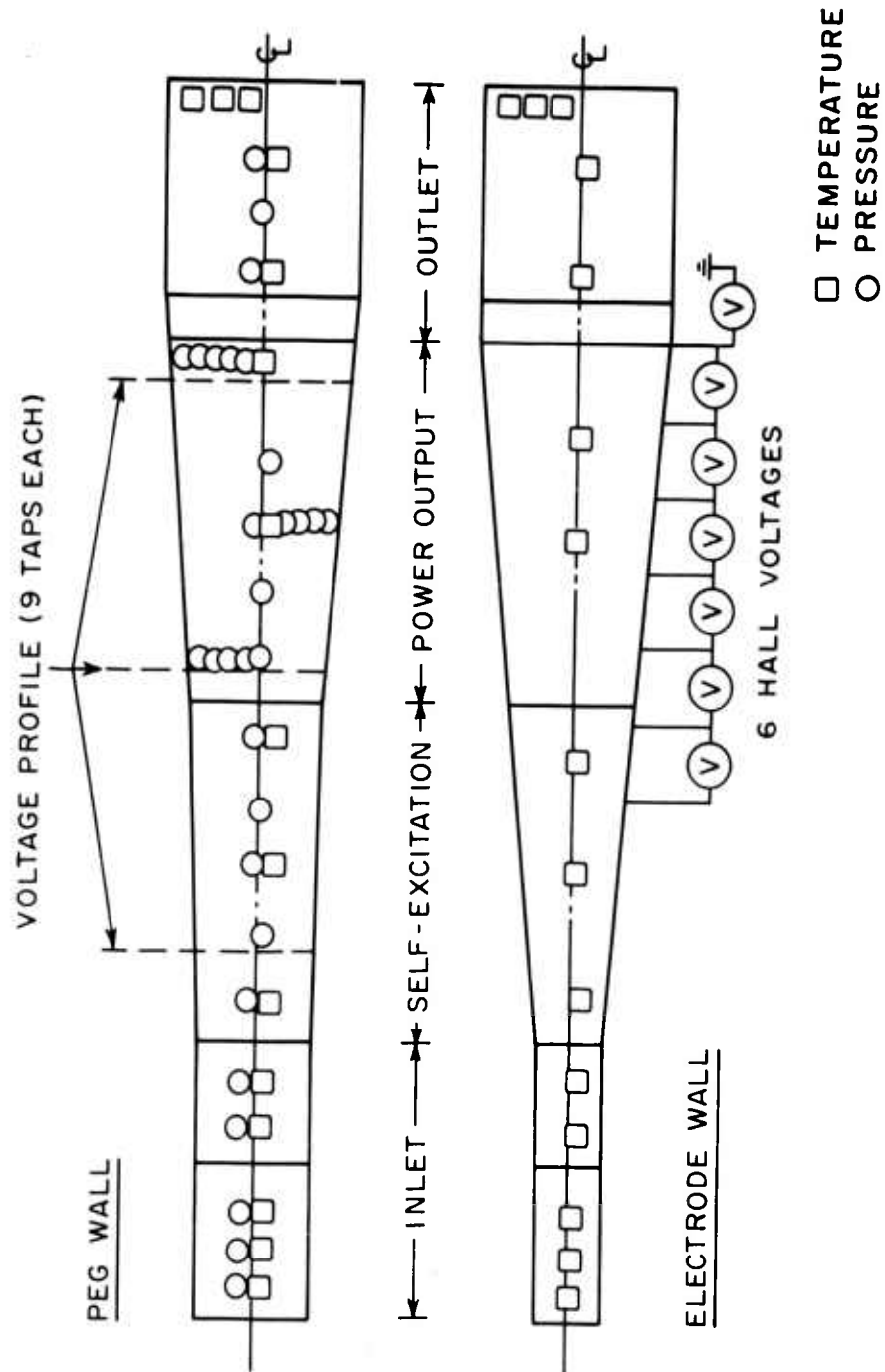


Figure V-1 Channel Monitoring Instrumentation

VI. TESTS AND CALIBRATIONS

Burner: The igniter burner has been set up and tested. Cooling water flow has been measured at 1-1/2 gpm, as required. Initial operation produced a chamber pressure somewhat lower than desired. Enlargement of the fuel and oxygen injectors, especially the latter, has increased the mass flow and reduced the excessive richness. The resulting chamber pressure of 255 psig is considered to be more than adequate.

The pilot burner has been calibrated and test runs have been made. Measured water flow rate is 9-1/2 gpm, and the corresponding safety factor on burnout is estimated to be greater than two. Oxygen and nitrogen flows were adjusted to give an oxygen-nitrogen ratio of one using a flow of .11 lbs/sec for each gas. The ethane flow used is .032 lb/sec. The pilot burner started smoothly and in two seconds a chamber pressure of 120 psi was indicated. All controls functioned properly except the burner shut-down was premature. This was caused by the slow response of the pilot chamber pressure switches which then caused the automatic shut-down of the igniter and pilot burner. The switches are being adjusted to permit continuous operation of the igniter and pilot.

Fuel System: The fuel system has been operated through the calibrating loop to check system operation and to compare the flow as measured by the venturi and the calibrating orifice. Good agreement between the two flow measurements was obtained. The average deviation was about 1% for all three sets of venturies and orifices. These measurements are relative values because one instrument is compared with another. When the fuel tank is completely calibrated, absolute measurements will be possible by comparing instrument values with actual measured flow. Calibration tests will be completed using water, then correcting values for the fuel.

Cooling water system: A calibration of cooling water flow rate versus pressure drop for the load resistor tubes and hoses has been performed. Calibration curves were made for each of the four tube sizes. A test rig was arranged to calibrate each tube individually, which measured the pressure drop across the tubes, the test time and the total water flow.

Tests of the load resistor cooling water system have been made using the main water pump. The system has been operated wide open with the water discharging into the exhaust duct. Up to 7000 gpm were pumped through the total load. Only a handful of leaks were experienced from the more than 4000 connections and these have been repaired.

The calibration of cooling water flow through the resistors has shown that the values used in calculation of heat transfer rate were conservative.

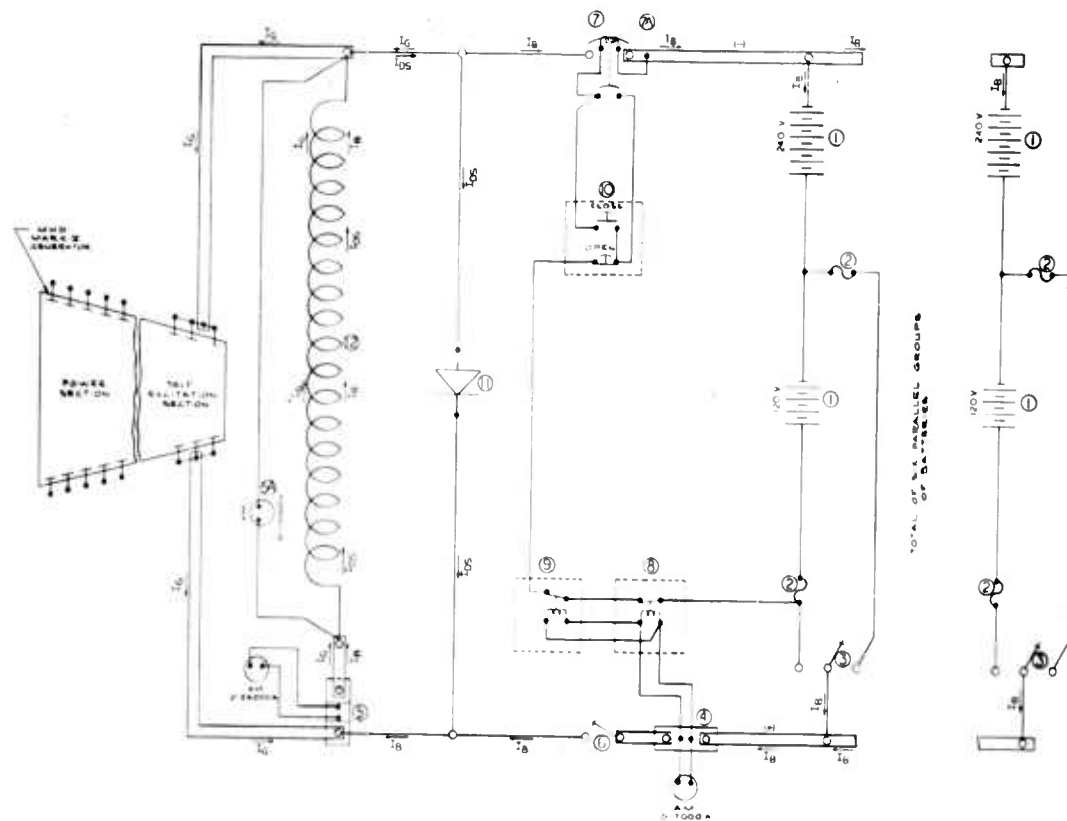
As a result of this study, it was possible to allow more cooling water flow to the channel walls where an added safety factor was desirable.

Magnet: The magnet has been brought up to the maximum current and field obtainable with the battery bank. Initial tests were conducted using a welding generator at about 500 amps. The current flow was brought up in steps while checking for electrical faults. The magnet was then powered by the battery bank at current values between 3000 and 6200 amps.

Figure VI-1 shows a diagram for the magnet control and exciter circuit. The various components and operation of this circuit have been tested. All other equipment and circuitry required to operate the generator have been tested and calibrated.

Field measurements were made at several locations along the magnet centerline to verify predicted performance. The field strength was measured by a pickup coil connected to an oscilloscope. The pickup coil produces a voltage which is proportional to dB/dt during magnet buildup. The field strength is determined by integrating the scope trace on the photograph.

Figure VI-2 shows the predicted and the measured field strength along the magnet centerline. The measured field strengths were about 1500 gauss greater than predicted due to the low reluctance path provided by the reinforcing steel. The actual maximum field strength will be 36,500 gauss at design current. Based on model tests the steel contribution was expected to be 1-2%, but it is actually 4%.



- 1 D. C. BATTERY POWER SUPPLY FOR SEPERATE EXCITATION OF FIELD MAGNET TO GIVE INITIAL GENERATOR OUTPUT TO SUSTAIN SELF EXCITATION OF GENERATOR.
(FIELD MAGNET HAS NOT ENOUGH RESIDUAL MAGNETISM TO SUSTAIN SELF EXCITATION)
- 2 FUSES FOR SHORT CIRCUIT AND REVERSE CURRENT PROTECTION OF D. C. BATTERY POWER SUPPLY
- 3 BATTERY VOLTAGE SELECTOR SWITCHES FOR SEPERATE EXCITATION
- 4 D. C. SHUNT FOR MEASURING BATTERY OUTPUT CURRENT.
- 5 D. C. SHUNT FOR MEASURING INPUT CURRENT TO FIELD MAGNET FROM EITHER THE BATTERY CIRCUIT OR GENERATOR CIRCUIT
- 5A D. C. VOLTMETER FOR MEASURING FIELD MAGNET VOLTAGE
- 6 KNIFE SWITCH FOR ISOLATING BATTERY CIRCUIT FROM FIELD MAGNET
- 7 D. C. CIRCUIT BREAKER
- 7A D. C. CIRCUIT BREAKER REVERSE CURRENT TRIP COIL (OPENS CIRCUIT BREAKER ON 500 AMPS OF REVERSE CURRENT).
- 8 CURRENT SENSING SAFETY DEVICE FOR AUTOMATICALLY OPENING CIRCUIT BREAKER AT SELF EXCITATION TAKE OVER POINT (OPERATES ON LOW FORWARD CURRENT, ADJUSTABLE FROM 100 A TO 1,000 A).
- 9 CURRENT SENSING SAFETY DEVICE FOR AUTOMATICALLY OPENING OF CIRCUIT BREAKER ON REVERSE CURRENT FROM GENERATOR AT SELF EXCITATION TAKE OVER POINT.
(OPERATES AT 50 AMPS OF REVERSE CURRENT)
- 10 PUSH BUTTON STATION FOR CONTROL OF BATTERY POWER.
- 11 FIELD DISCHARGING RECTIFIER (FREE WHEELING) [CONSISTS OF 88 RECTIFIERS IN SERIES AND 44 PARELLEL EACH RATED 250 A @ 600 V. PRV]
- 12 FIELD MAGNET
- 1B CURRENT FLOW OF BATTERY POWER SUPPLY
- 1G CURRENT FLOW OF GENERATOR
- 1DS DISCHARGE CURRENT FLOW THROUGH RECTIFIER UPON COLLAPSING OF THE FIELD FOR SELF DISCHARGING.

Figure VI-1 Schematic of Magnet Control and Exciter Circuit

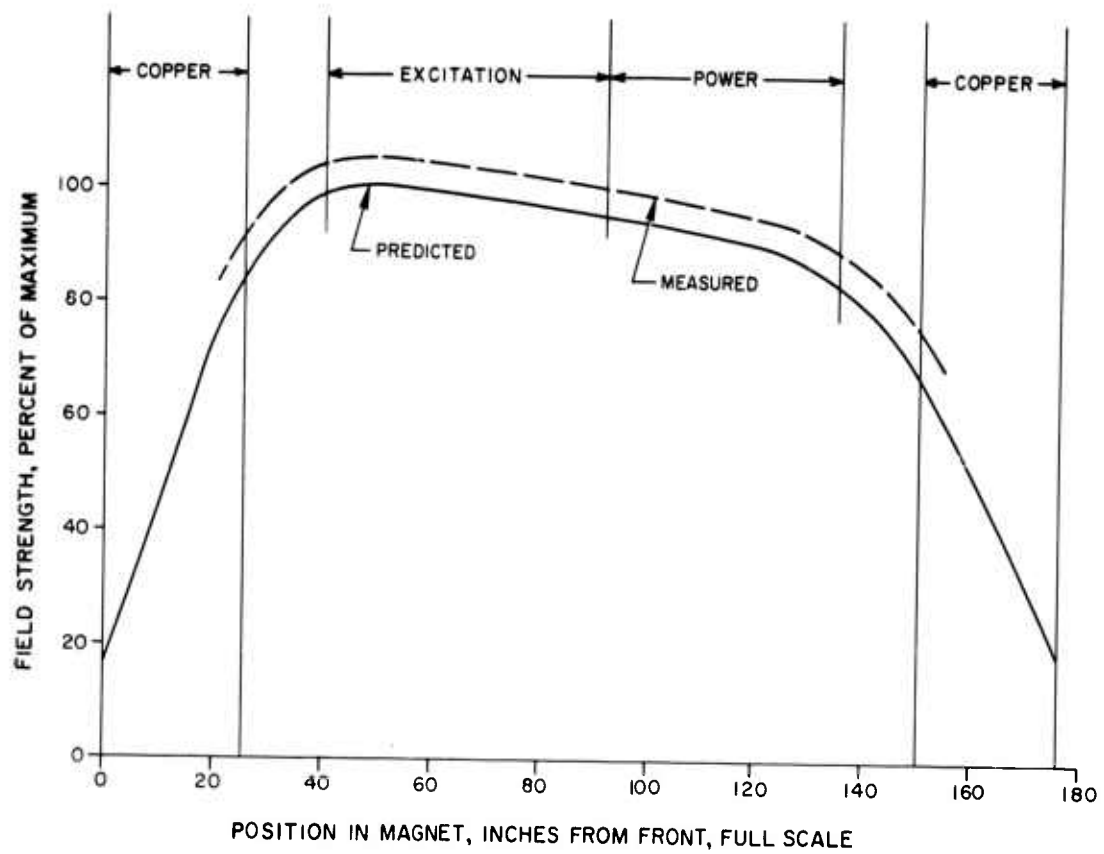


Figure VI-2 Measured and Predicted Longitudinal Centerline Field Strength, Mark V Generator Magnet

VII. STATUS OF CONSTRUCTION

1. Burner: Fabrication of the nozzle sections was somewhat delayed due, in part, to an internal reorganization of one of the subcontractors. The time lost was not great enough to affect the overall program. In the injector section more serious problems, described in Section II, were encountered, and a time loss produced which has delayed the completion of the burner testing program.

The burner liner and nozzle have been completely assembled. The finish machining of the rebuilt injector plate is completed, and the plate is in the process of being installed, after which the burner will be ready for final testing.

Figure VII-1 is a photograph of the burner assembly, showing the burner and nozzle mounted on the burner cart with the necessary manifolds and supply lines. In the foreground are the control valves with the pilot burner above on a temporary mounting for initial tests.

2. Auxiliary Systems: The fuel room is completed as shown in Fig. VII-2. The entire system has been checked for leaks, the tank properly calibrated, and the pump run using water as the flow medium. All units were found to be satisfactory and ready for use.

The oxygen and nitrogen systems have been completed including the installation of the storage tanks, the pipelines, the control valves, Fig. VII-3, and the connections to appropriate units, along with the instrumentation required. Both storages have been pressurized to their working capacities and have been used in the testing of the igniter and pilot burners.

The burner control panels are installed and operational, Fig. VII-4. The entire system has been tested electrically, and the firing of the igniter and pilot burner has been successfully completed.

3. Channel: All materials required to complete the channel assembly have been received. This includes special tooling, pressure checking equipment, and instrumentation.

The nature of the channel design is such that the insulating peg wall for the bottom of the channel is identical to the top wall, and the electrode wall on one side is identical to the opposite wall. The complete insulating peg wall, as well as the complete electrode wall, are each made up of three sub-assemblies. The assemblies are designed as described in Section IV, Channel Design, of the Semi-Annual Technical Summary Report, dated March 1963. Figure IV-1 of that report is reproduced here as Fig. VII-5 for reference.

To fully visualize the present status of channel assembly, a brief description of the sub-assembly status is presented:

- a) Inlet Insulating Walls: Both walls are assembled with the exception of refractory. Installation of instrumentation has been completed.
- b) Self-Excitation and Power Section Insulating Walls: The bottom wall is assembled and ready for mounting to the channel chassis. The top wall is 90% assembled. The installation of pressure and temperature instrumentation on this wall has been completed.
- c) Exit Section Insulating Walls: Both walls are assembled with the exception of refractory.
- d) Inlet and Self-Excitation Electrode Walls: Both walls are approximately 60% assembled. Insulation must be placed between the stainless steel support bars and between the copper electrodes.
- e) Power Section Electrode Walls: Both walls are approximately 25% assembled at this time.
- f) Exit Section Electrode Walls: One wall is 90% completed, as seen in Fig. VII-6. The remaining wall is 80% completed.
- g) Chassis and Roll-out Stand: The roll-out stand and chassis are ready to accept the final assembly of the channel walls. Final assembly has been started.

Final assembly of the channel sub-assemblies should now progress quite rapidly. The sub-assemblies remaining to be assembled will be worked on simultaneously with the assembly of the already completed wall sections.

4. Magnet: The Mark V Generator Magnet has been completely assembled and tested using the battery power supply as reported in Section VI. Figure VII-6 is a photograph of the completed copper portion of the magnet.

Figure VII-7 is a photograph of the completely assembled magnet showing the steel reinforcement.

5. Magnet Control and Exciter: The installation of the magnet control and exciter, including the interlocking of the magnet control with the burner control, has been completed and tested.

The assembly of the load resistors has been completed and pressure checked with the exception of installation of the load leads between resistors

and the generator channel, Fig. VII-8. Fabrication of all parts required for the electrical connections has been completed.

6. Instrumentation: The design of all instrumentation has been completed as described in Section V. All thermocouples and pressure gauges have been installed and are ready for operation. The only remaining work to be done on instrumentation is the installation of electrical taps and leads from the load resistors to the instrumentation panel. At the present time, the instrumentation is ready for burner testing. A photograph of the Mark V instrumentation panel and cameras may be seen in Fig. VII-9.

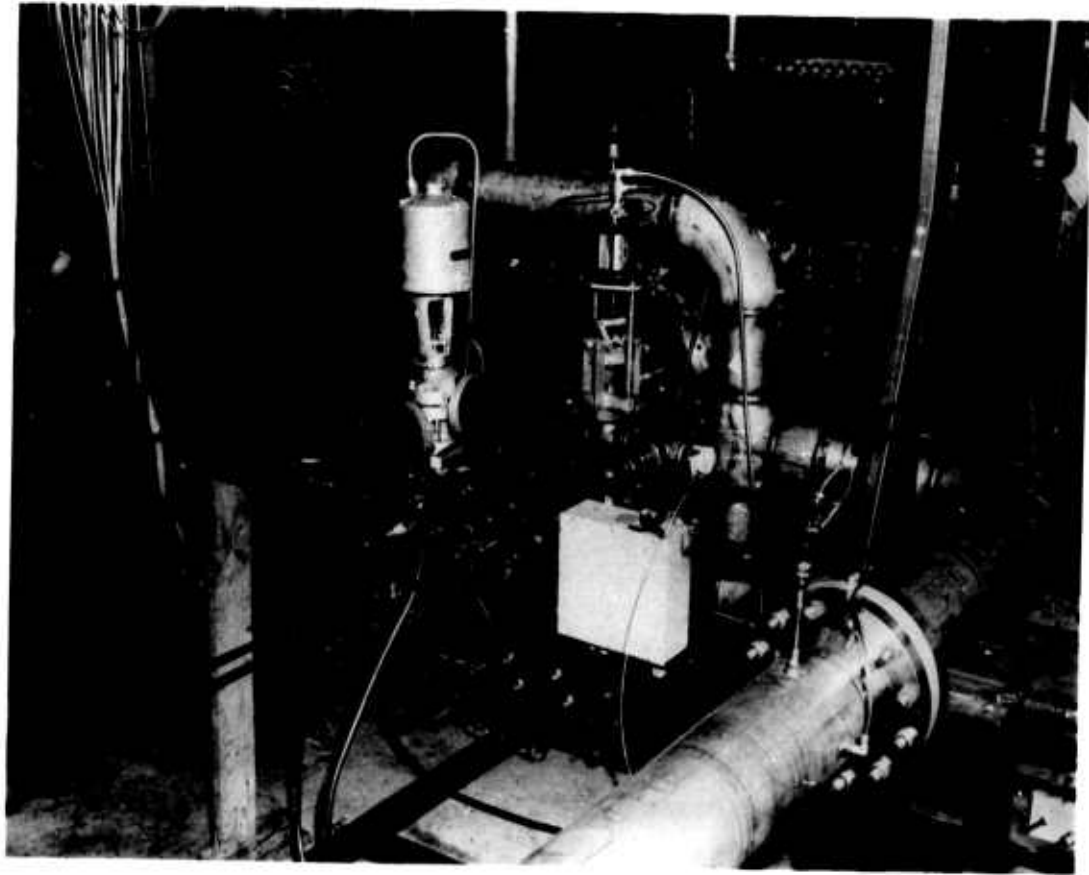


Figure VII-1 Present Status of Mark V Burner Assembly

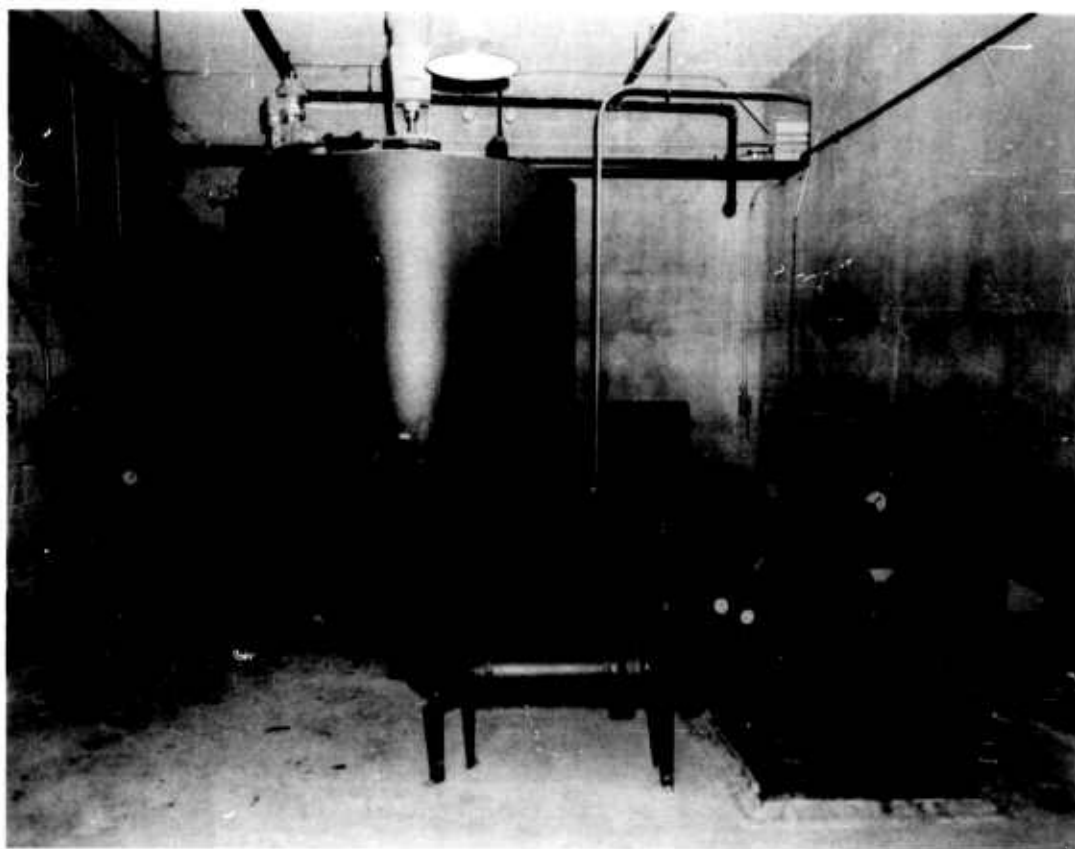


Figure VII-2 Photograph of Completed Fuel Room

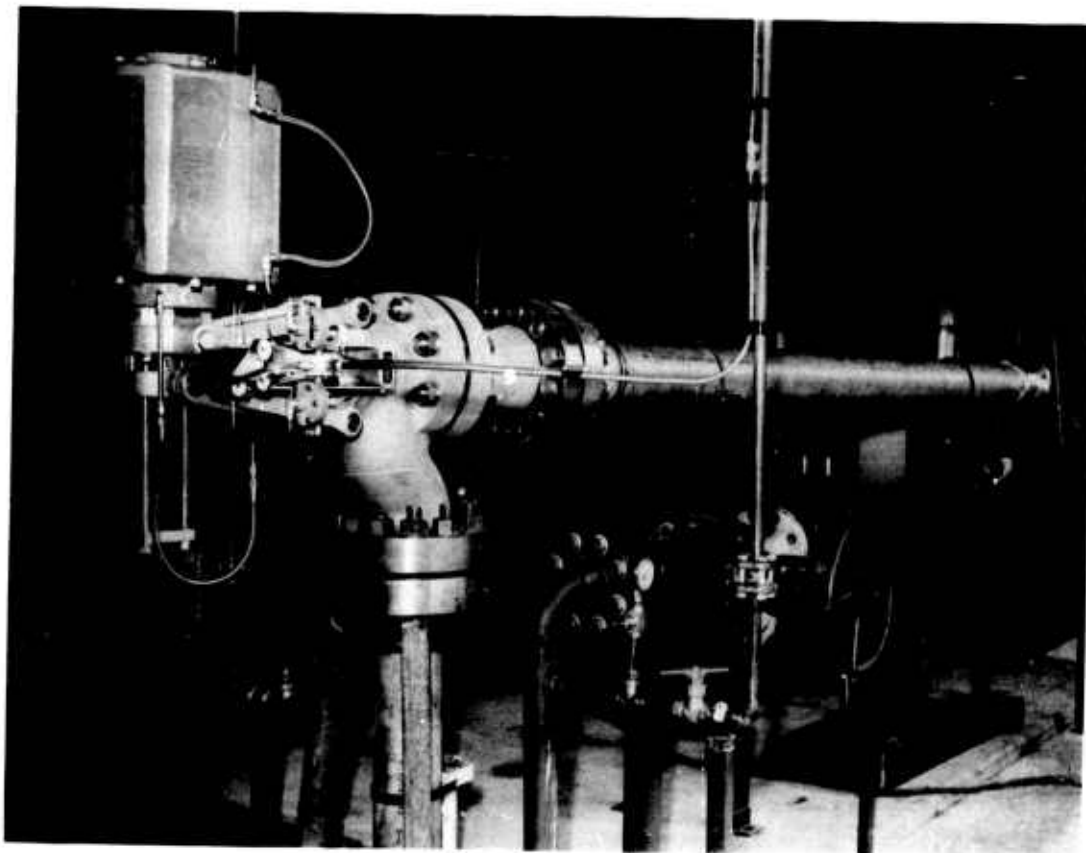


Figure VII-3 Main Oxygen and Nitrogen Control Valves

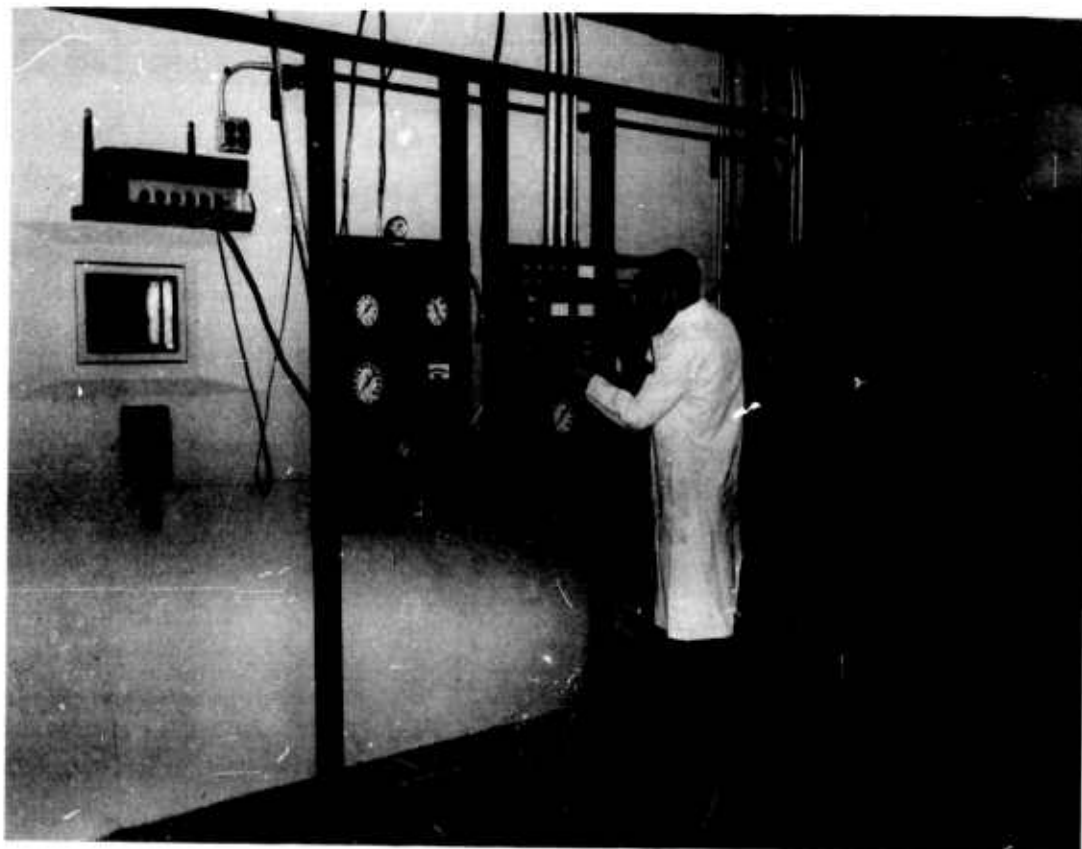


Figure VII-4 Completed Mark V Generator Control Panels

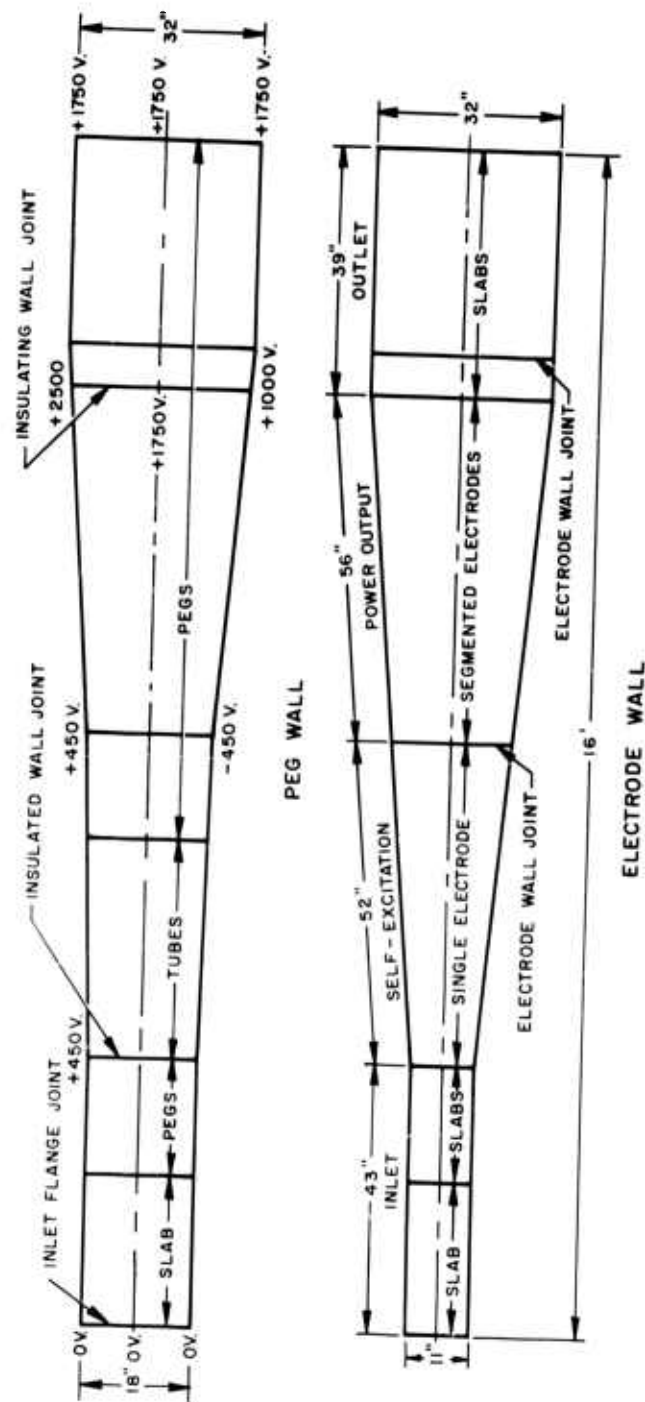


Figure VII-5 Mark V Generator Channel Layout.

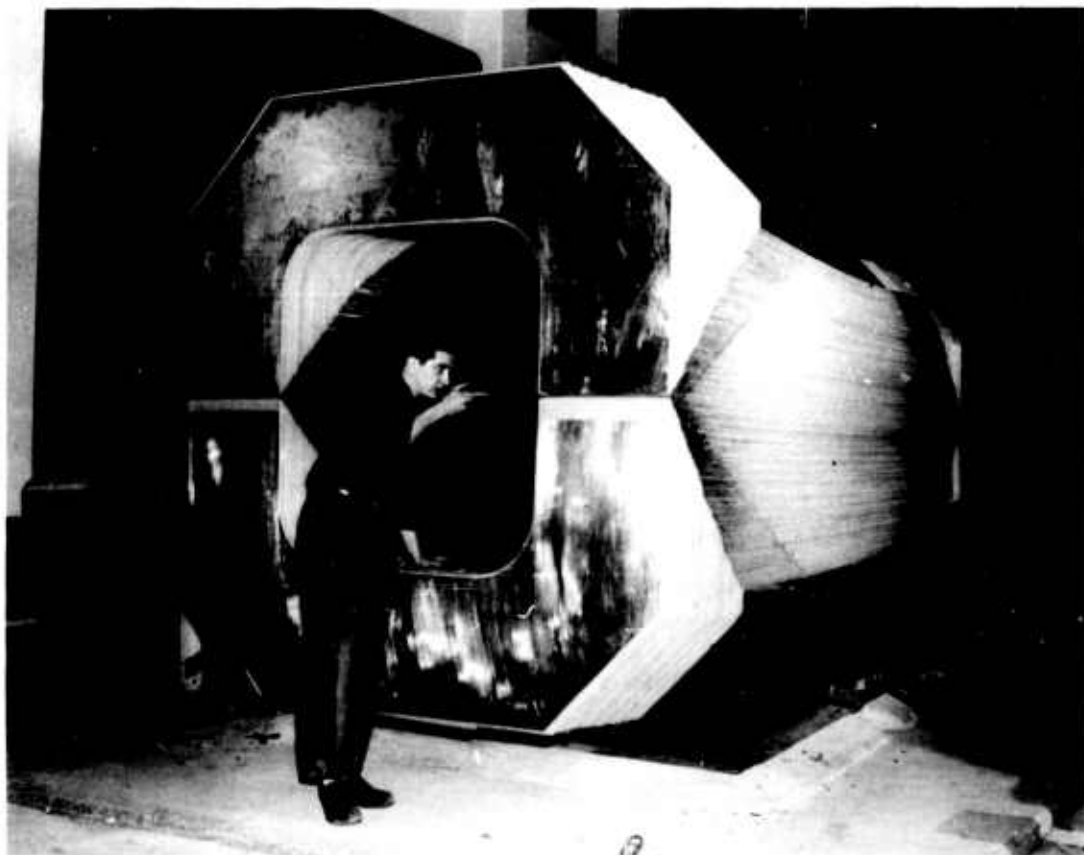


Figure VII-6 Copper Portion of Mark V Magnet

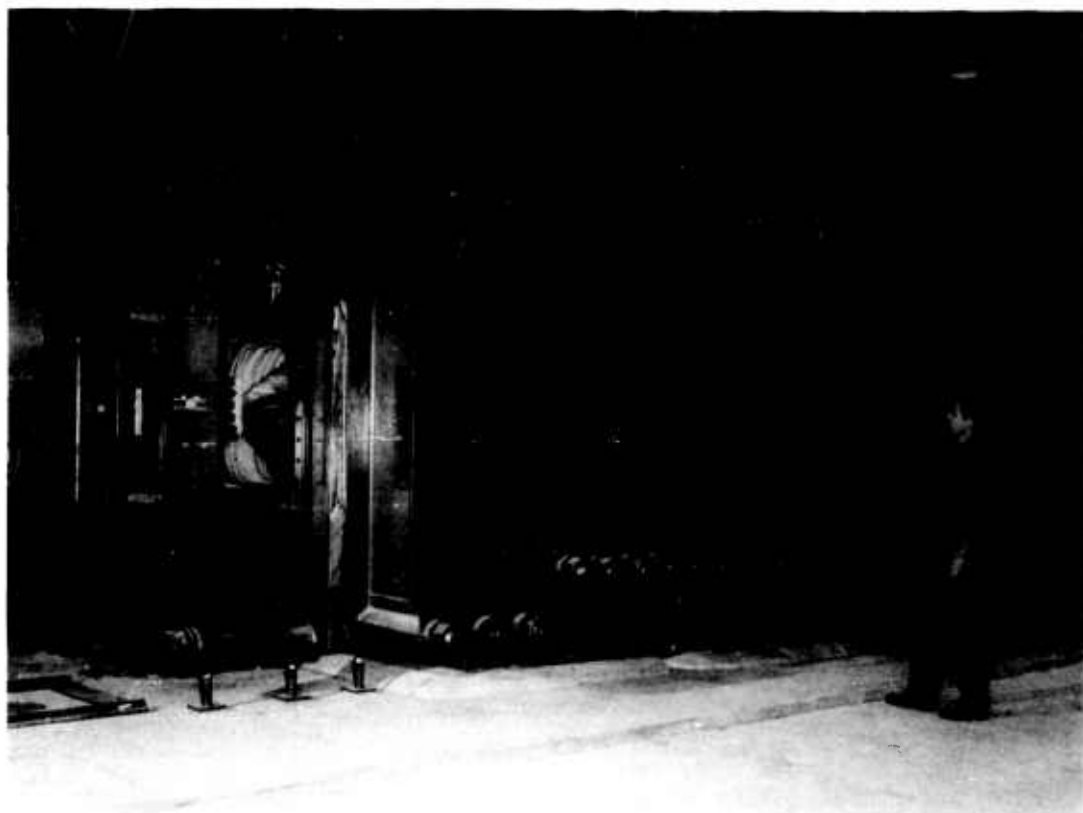


Figure VII-7 The Completed Mark V Field Coil

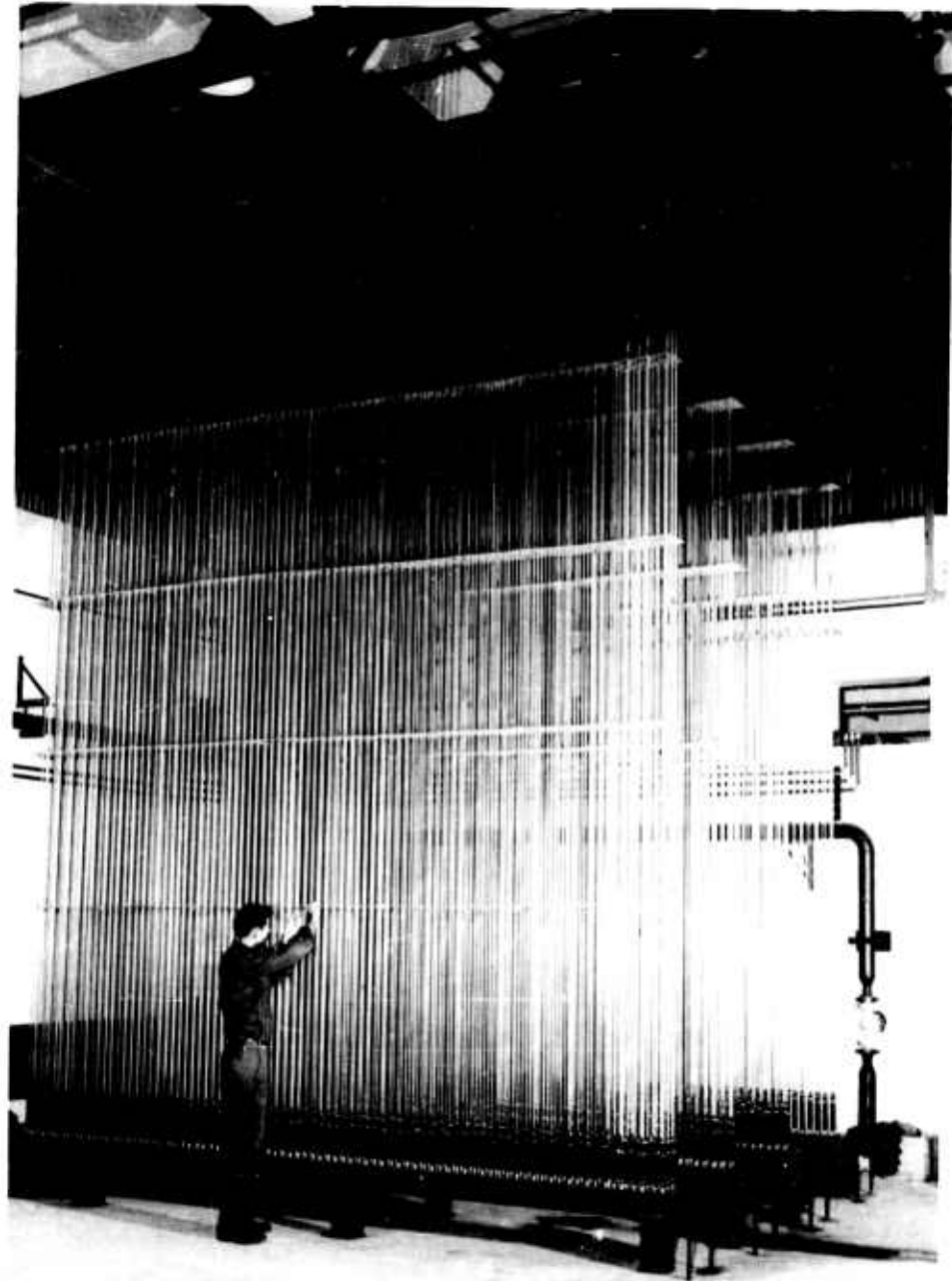


Figure VII-8 Generator Load Resistor Assembly

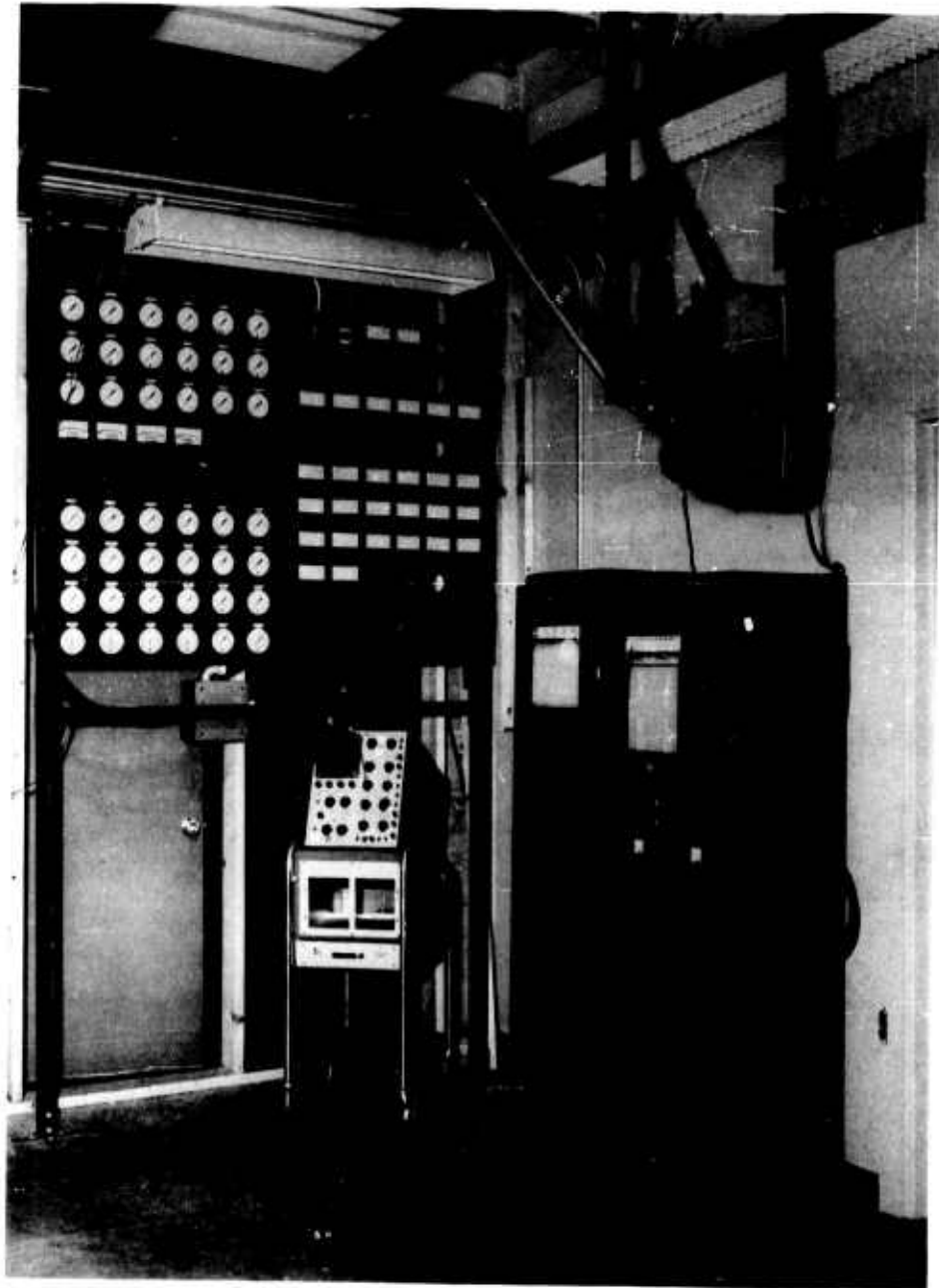


Figure VII-9

Partially Assembled Instrumentation Panel,
Recorders and Cameras

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